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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. X. BOSTON, MASS., DECEMBER, 1893. No. 8.

THE WINDS OF THE INDIAN OCEAN.*

PROF. WILLIAM MORRIS DAVIS.

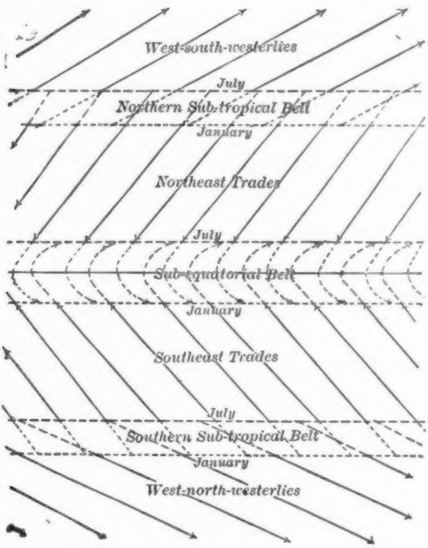
THE monsoons of the Indian Ocean are commonly referred to in illustration of the effect of a continent in disturbing the otherwise symmetrical arrangement of the trade winds ; but according to the best modern charts, they illustrate also a peculiar deformation of the trade winds, independent of continental action, to which attention should be directed. This deformation is seen in the occurrence of a narrow belt of monsoon winds south of the equator, to which the name of terrestrial monsoons may be given, in distinction from the continental monsoons, north of the equator.

In articles on "A Classification of the Winds," published in this JOURNAL for March, 1888, and on "The General Winds of the Atlantic Ocean," in the JOURNAL for March, 1893, I have given a brief account of the general plan of a classification of the winds, which has been employed in my teaching for several years, and which appears to me more satisfactory, from being more natural and less empirical, than the classification usually employed, in which winds are classed as permanent, periodic, and variable. This simple and older plan is probably better suited, as many empirical methods are, to the practical man, who only wishes to use but not to enjoy his knowledge ; but it does not satisfy the student, who employs a classification chiefly to aid him in looking into the natural relations of phenomena. In the classification referred to, a northward and southward migration of the several members of the general *planetary circulation*

* Read before the New England Meteorological Society in Boston, Oct. 21, 1893.

was presented as the chief characteristic of the circulation on our own earth, which was hence called the *terrestrial circulation.* I wish now to refer particularly to the effect of the migration of the doldrums on the winds of the sub-equatorial belt, across which the doldrums travel.

The accompanying diagram will make my meaning clearer. If the axis of the equatorial belt of low pressure remained fixed on the geographical equator, the trades would approach sym-



metrically from either side and fade away in the intermediate doldrums. But when the doldrums pass to the north of the equator, in the late northern summer, the northeast trades are cut short, and the southeast trades are tempted to pass out of their proper hemisphere. They continue all the way on northward gradients, but they pass from a latitude in which an austral* deflection turns them to the left and enter a latitude in which a boreal deflection turns them to the right; thus the southeast trade of the southern hemisphere, swings around and becomes

* Following the terminology adopted for the aurora, I shall use the terms *boreal* and *austral* as referring to the northern and southern hemispheres.

a southwest wind on our side of the equator. It may be called a monsoon wind, because in the opposite season this half of the sub-equatorial belt is occupied by the normal trade wind from the northeast. When the doldrums pass south of the equator in the late southern summer, a northwest monsoon wind should be formed by the extension of the northeast trade wind.

It should be noticed that these monsoons do not depend at all on the presence of continents; they are simply special features of planetary winds on an earth, whose axis is distinctly inclined from the vertical to its orbit, and whose year is long enough to cause a significant migration of its heat equator. It is not only true that continents are unessential to the development of these monsoons; they may even destroy the normal terrestrial monsoons. Such is the case in the South Atlantic, where the unsymmetrical outlines of Africa and South America require such an arrangement of ocean currents as to prevent the doldrums from moving significantly south of the equator. Hence there are no terrestrial monsoons in the South Atlantic. But where special disturbing influences are absent, terrestrial monsoons should be expected. Examples of their occurrence will be referred to further on.

On the other hand, where the location of continental areas, with respect to the geographical equator, is such as to tempt the belt of high temperature and low pressure to migrate over a great range of latitude, the alternation of the monsoon winds with the seasons becomes conspicuous. A series of monthly isobaric and isothermal charts, such as those prepared by Buchan for his "Challenger" report, should be consulted in order to determine where the heat and barometric equators migrate to land areas at exceptionally great distances north or south of the geographical equator, as well as to determine their migration under normal terrestrial conditions. The north and south migration of the heat equator following the sun is strong over Africa, and there we might expect well-marked examples of continental monsoons on both sides of the equator; but in the interior of the dark continent, the winds are little studied. The migration is strong to the north upon India in our summer; and distinct to the south over Australia in the summer of the southern hemisphere; in both of these regions, monsoons should be unsymmetrically developed in northern and southern lati-

tudes. The migration is moderate to the south on the open Indian Ocean between Africa and Australia; there a moderate development of purely terrestrial monsoons should be expected; and these taken with the continental monsoons of the adjacent lands make the Indian Ocean of special interest in studying this subject.

Before examining the modern maps of this ocean, let us briefly refer to two older accounts of its winds. We may quote from Dampier, the old navigator, who wrote about 1700; and from Capper, an officer of the East India Company, who wrote about 1800.

Old Dampier tells us, after speaking of the shifting trade winds in the Red Sea, that: "From Comorin, clear round the Bay of Bengal, the change is no less; and even from thence, through the Streights of Malacca, and eastwards as far as Japan, the shifting trade winds do alternately succeed each other as duly as the year comes about." All round the Bay, the winds "shift in the shifting seasons, which are April and September, at one and the same time, to their opposite points: I mean on the open coast, for in some bays there is a little alteration from that general rule. These shifting winds in the East Indies are called monsoons; one is called the east monsoon, the other the west monsoon. The east monsoon sets in about September and blows till April, then ceaseth; and the west monsoon takes place and blows till September again. . . . The east monsoon brings fair weather; the west brings tornadoes and rain. For . . . when the sun comes to the north of the line, then all places north of the equator, within the tropics, are troubled with clouds and rain, but when the sun is in southern signs then the sky is clear. . . . And tho' these winds do not shift exactly at one time in all years, yet September and April are always accounted the turning months, and do commonly participate of both sorts of winds. . . . For these monsoons do as constantly shift by turns, as the year comes about. And by means of this change of wind, ships have the benefit to sail from one part of India, with one wind, and return with the contrary: so that most of the navigation in India depends on the monsoons. And ships do constantly wait for these changes; and the merchants fit out to any place according as the season of the year draws on: And wheresoever they go, they certainly dispatch their business so

as to return back again with the next or contrary monsoon: for here is no sailing to and from any place but with the monsoon; one carries them out, the other brings them back." (Dampier's "Voyages," London, 1705, Vol. II., Part iii., 20–23.)

Dampier's rough charts of the winds represent a constant trade wind for the greater part of the South Indian Ocean within the torrid zone; but north of the equator all along the southern and eastern coasts of Asia, up to Formosa, paired arrows in opposite directions are drawn to indicate the alternating monsoons.

Capper's account of the monsoons is not very explicit as to times and places of occurrence; but he introduces mention of a feature to which Blanford later gives prominence; namely, the deflection of the wind in certain districts from its ordinary course. His statement on this point is as follows: "In tropical countries there are but two seasons: those in Hindustan are distinguished by the northeast and southwest monsoons. But farther to the eastward and southward of the line, and the Gulf of Bengal, the monsoons blow from different quarters. The northeast becomes in those parts the northwest and the southwest becomes the southeast." ("Observations on the Winds and Monsoons," London, 1801, 40, 41.) It is not plain whether Capper here refers to the deflection of the monsoon winds up and down the plain of the Ganges; but he seems to refer certainly to the austral deflection of the winds south of the equator. His essay has no map of the winds, and his text is not perfectly clear. Giving him the benefit of the doubt, it appears that in the above brief sentence we have the first recognition of the facts to which I wish to give special emphasis in this essay.

It may be noted in this connection that Capper is most frequently referred to nowadays as one of the earliest authors to recognize the whirlwind character of the cyclones of the Bay of Bengal, to which he devotes a number of pages. He does not describe their winds very clearly, nor does he specify the direction of their vorticular rotation; but in trying to explain their cause, he seems to adopt a suggestion of Franklin's in ascribing small whirls to ascending currents, and larger storms to the descent of unduly cooled and heavy air from the upper regions of the atmosphere. Then "the parts adjacent will immediately concentre to a point, and rush with a whirling circular motion

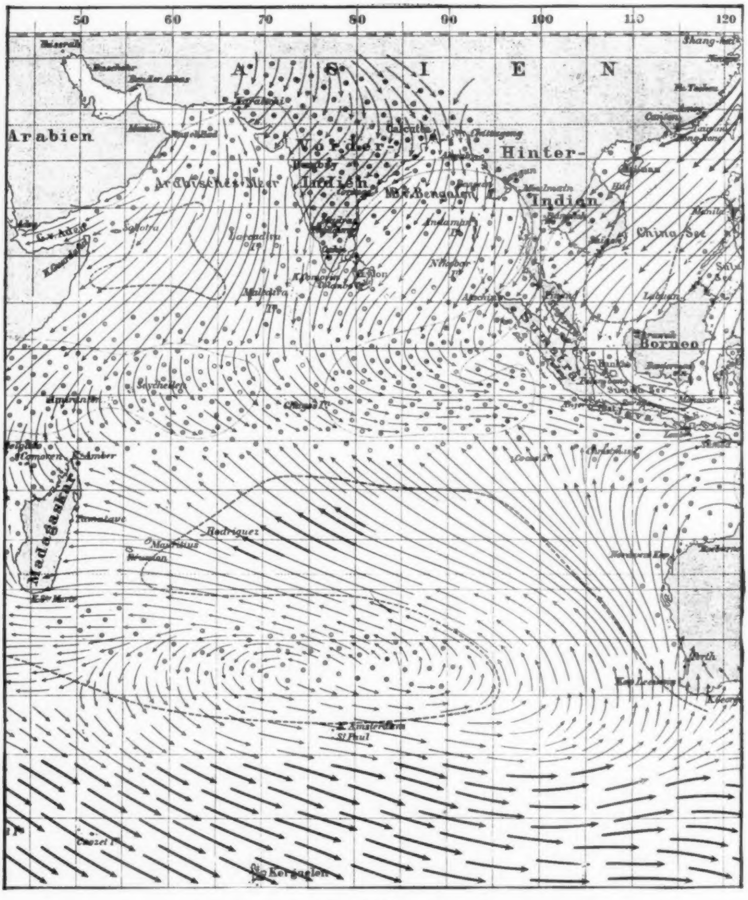
towards the bottom with great violence. . . . It would not, perhaps, be a matter of great difficulty to ascertain the situation of a ship in a whirlwind, by observing the strength and changes of the wind. If the changes are sudden and the wind violent, in all probability the ship must be near the centre or vortex of the whirlwind; whereas, if the wind blows a great length of time from the same point, and the changes are gradual, it may be reasonably supposed the ship is near the extremity of it." (*Ibid.*, 65, 66.)

As stated at the beginning of this essay, modern writers seldom make mention of the austral deflection experienced by the northeast trade, when it crosses the equator and enters the southern hemisphere as a northwest wind. Let us, therefore, next examine the best recent chart of this ocean, and see how it presents the facts.

The facts of the case, without regard to classification or theory, but generalized on the basis of the fullest possible collection of observations, are best represented in two maps here reproduced from the Atlas of the Indian Ocean, in chief part prepared by Dr. W. Köppen, and published by the German Marine Observatory, at Hamburg.*

Chart I is for January and February, the late summer of the southern hemisphere, when the heat equator and the belt of low barometric pressure have advanced to about latitude 10° S., in the middle of the Indian Ocean. The heavier arrows show stronger winds; the longer arrows, steadier winds. On this chart, the southern tropical belt of high pressure is broken on the warm lands of Africa and Australia, and a flattened but distinct anticyclonic system of outflowing winds is seen around the localized oval area of high pressure midway between Australia and South Africa. All these features of temperature and pressure, as well as of winds, are finely exhibited by special charts in the atlas referred to above. South of the anticyclone, we see the strong west-northwest winds, forming a part of the

* Indischer Ozean. Ein Atlas von 35 Karten. Beilage zum Segelhandbuch für den Indischen Ozean. Deutsche Seewarte, Hamburg, 1891. The Segelhandbuch gives a full account of the winds. In my reference to the similar maps in the atlas of the Atlantic Ocean, in the Journal for last March, I should have mentioned the name of Dr. Köppen, as the meteorologist chiefly responsible for the preparation of the charts.



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great whirling circulation around the south pole; north of the anticyclone flow the trade winds, normally from the southeast, but locally deflected to a more southerly course near Australia, and a more easterly course near Africa. North of the equator, the northeast trade blows with much regularity over the waters; its strength being greatest on the western Pacific, and least over the peninsula of India, where, as Blanford points out, the windmill has not been employed in pumping water in the dry season, although the natives have had sufficient ingenuity to invent other mechanical devices for use in irrigation. The weakness of the wind there is primarily due to the faintness of the gradients which cause it; secondarily, to the obstruction offered by the inequalities of the land surface; and finally to the absence of local convection in the cooler season, by which the surface and overlying currents may be mixed and a greater velocity given to the wind close to the ground. The course of the northeast monsoon is significantly deflected on certain parts of the peninsula and in the great gulfs on either side, — the Bay of Bengal and the Arabian Sea, — so that Blanford advises that it should be called the winter monsoon. In Bengal, it comes from the northwest; west of Bombay, it comes from the north. All of this is, however, aside somewhat from the chief interest of the map.

As the barometric equator lies ten degrees south of the geographic equator, the northeast trade wind does not stop at the latter limit; but passes into the southern hemisphere; and then promptly swings around and becomes a northwest wind. This is probably the "N.W." that Capper described as occurring "southward of the line." Approaching Java, this wind advances almost directly eastward, to take part in the austral cyclonic inflow or continental monsoon over Australia; while near Africa, it comes from the north, or even maintains its northeast source, on its way towards the heated interior of that continent.

It is manifest that the northwest wind, south of the equator in the middle of the Indian Ocean, is a purely terrestrial product; as such, it is the best example of its kind yet charted. In the Atlantic, the form of the continents and the consequent course of the ocean currents, taken with the comparative narrowness of that ocean at the equator, prevents the development of a

distinct monsoon wind in mid-ocean ; although near the African coast, north of the equator, a hybrid monsoon, partly terrestrial, partly continental in origin, is seen in the northern summer. In the Pacific, there is breadth enough ; indeed, too much for successful study at this date. The expanse of waters is there so vast, and the observations are relatively so few, that our knowledge of that ocean is not yet sufficient for the construction of maps like those which now so well illustrate the meteorological features of the Atlantic and Indian oceans ; but of this more, below, in connection with some remarks on currents.

Turning now to the second chart, representing the average winds for July and August, we may first note a general increase in velocities over the Indian Ocean, and a decrease over the Western Pacific. The increase over the Indian Ocean is due, in the southern hemisphere, to the increased strength of the circumpolar gradients ; and in the northern, to the excessively high temperatures in Northwestern India. In examining the directions of the wind, there is little change to be noted in the southern part of the ocean. The division between the westerlies and the southeast trade is somewhat more linear than before ; because the tropical belt of high pressures is now less interrupted on the lands than it was in the southern summer ; but there is still a well-marked northward branching from the westerlies into the trade along the western coast of Australia. The position of the high pressure belt is about five degrees more northward than before ; this being a consequence of the increased velocity of the circumpolar whirl, as was described in my former paper. Anticyclonic outflows of air now appear over Australia, and to a less degree over Africa also, as these lands are now centres of relatively low temperatures, being cooler than the surrounding seas.

The extension of the southeast trade wind across the equator, as the southwest or summer monsoon, is the most striking feature of this chart. The obedient manner in which this vast current of air changes from an austral to a boreal habit of deflection, on passing from one hemisphere to the other, is nothing less than admirable. How anyone can question the sufficiency of the rotation of the earth to influence the course of the winds in face of such facts as these is really mysterious. The southern half of the torrid zone is occupied, over the open ocean, by a

normal trade wind of much strength and remarkable constancy, both in direction and persistence; the northern gulfs of the ocean have as strong and as steady a wind, but it comes from the southwest; yet in both cases the wind moves on northward gradients. The belt of weaker and less constant winds, with not infrequent calms along the equator, is seen, by comparison with the chart of temperatures, to result from a belt of weak temperature gradients, and hence weak barometric gradients; these being the representative of the extinguished doldrums, now supplanted by the belt of low pressure in Southern Asia. In this connection, it may be noted that the development of the terrestrial monsoon in the southern hemisphere, and of the continental monsoon in the northern hemisphere, are unlike in a certain respect. The southward advance of the doldrums from the equator to their most southern position, where they stand in January or February, is accomplished by a steady migration; and the inflowing trade wind, deflected according to the hemisphere that it occupies, simply follows this migrating belt of high temperature and low pressure. But when the sun moves north and the doldrums start after it, there is no such regularity of migration all the way to the northern position of the summer belt of low pressure. When the doldrums have returned to the equator in April, the rise of temperature over Northern India becomes so rapid that the seat of highest temperatures and lowest pressures is, as it were, at once transplanted to latitude 25° north; and then the winds are no longer satisfied on reaching the doldrums, but blow onward to this new goal. The former position of the doldrums is then marked only by the belt of weaker winds and occasional calms along the equator, as already mentioned. Five or six months later, the belt of low pressure is transplanted from its abnormal position on Northern India to the true doldrum belt; and then the regular southward migration is established.

The deflections of the monsoon on reaching India are as noticeable as were those of its predecessor six months before. It blows almost from west to east across Southern India; while over the plains of the Ganges it is a southeast wind. Hence, as far as the peninsula is concerned, it had better be called, again following Blanford, the summer monsoon, after its season, and not the southwest monsoon.

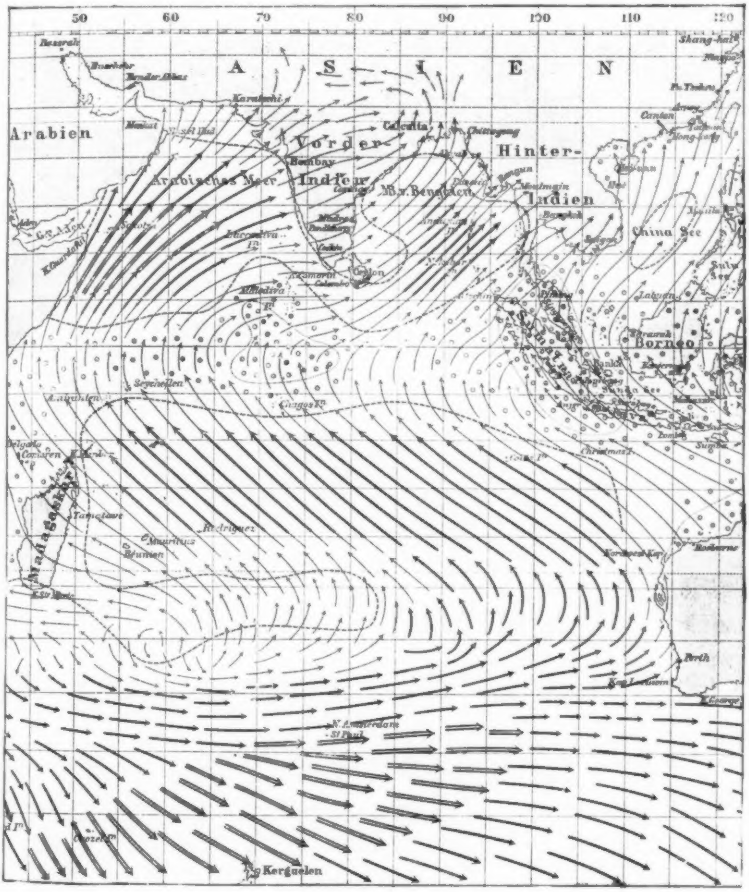
In view of all these facts, it seems not too much to say that any account of the monsoons of the Indian Ocean is incomplete if the terrestrial monsoons of the southern hemisphere are omitted. Although less famous, less conspicuous, and less important in their practical relations than the continental monsoons, they deserve careful recognition by the student of meteorology.

A brief postscript is suggested concerning the currents of the Indian Ocean. It is interesting to notice that even at the time of Dampier's voyages, the relation of the currents around India to the monsoons had been noticed. He says: "On the coast of India, north of the line, the current sets with the monsoon, but does not shift altogether so soon, sometimes not by three weeks or more, and then never shifts again till after the monsoon is settled in the contrary way. As, for example, the west monsoon sets in the middle of April, but the current does not shift till the beginning of May; so when the east monsoon sets in about the middle of September, the current does not shift till October." ("Voyages," Vol. II., Part iii., 107.)

The relation of cause and effect between winds and surface currents thus appears to have been clearly brought out two hundred years ago.

In another respect, these currents are of peculiar interest. All the great oceans possess eddy-like currents, turning from left to right in the northern hemisphere; and from right to left in the southern. The equatorial members of each eddy, therefore, advance from east to west, and might work closely together, if it were not for the equatorial counter currents, which in both the Atlantic and the Pacific more or less completely separate the adjacent members of the normal eddies. The counter current of the Pacific is always represented somewhat north of the equator; and I suspect that its best development will be found to be in the late northern summer, when a terrestrial monsoon appears to occur just north of the equator in the Pacific; but we have little information on this point. The counter current of the Atlantic, commonly called the Guinea current, lies distinctly north of the equator, increasing in length in our summer, when the hybrid southwest monsoon of that region has its greatest development.* In confirmation

* The Winds and Currents of the Equatorial Atlantic. Amer. Met. Journal, I., 1884, 53, 54.



WINDS OF THE INDIAN OCEAN. — JULY, AUGUST.

of the explanation that refers the equatorial currents to the monsoon winds near the equator, we may look at the special arrangement of the currents in the Indian Ocean.

When the sun is north of the equator, and the southwest monsoon is produced, there is a strong eastward current along the northern border of the ocean ; it is irregular on account of the uneven form of the ocean's outline, but as it moves eastward within the torrid zone, it may be called a counter current. South of the equator, the normal right-to-left eddy wheels around in its everlasting circuit.

When the sun is south of the equator, and the narrow terrestrial monsoon is blowing from the northwest across the southern sub-equatorial belt, there is a counter current formed beneath it, while the northern part of the ocean is occupied by a current moving westward, and thus simulating the equatorial portion of a boreal eddy. The semblance is imperfect, for this westward marginal current joins forces with the equatorial counter current, and the two make an eddy turning in the wrong direction, and not in gear with the eddy of the southern hemisphere.

So far as the comparison goes, it is not unfair to say that in this ocean, where monsoons are developed on both sides of the equator, according to the season, the counter currents also occur on both sides of the equator, accordant with the winds. The Atlantic and Pacific have the monsoon element only north of the equator; and their counter currents inhabit only the northern hemisphere, close to its border. The Indian Ocean has a better developed monsoon system, now on one side of the equator, now on the other; and the position of its counter current also oscillates from the northern to the southern side of the line.

HARVARD COLLEGE, Nov. 1, 1893.

SOUTH AMERICAN METEOROLOGY.*

PROF. WILLIAM H. PICKERING.

IT is a well-known fact that the deserts of the world lie in two zones, situated just along or just outside of the two tropics. Their general trend is, therefore, east and west. There is,

* Read before the New England Meteorological Society in Boston, Oct. 21, 1893.

however, one notable exception to this rule. This is the great desert which extends along the west coast of South America, reaching from Cape Parina on the north nearly to Valparaiso on the south, a distance of eighteen hundred miles. The explanation usually given for the existence of this desert is that the winds in the tropics blow pretty uniformly from the east, and that they carry the moisture from the Atlantic Ocean across the continent, depositing the last vestige of it upon the high mountains, so that when the air finally reaches the western side of the Andes, it is devoid of all moisture, and that rain, therefore, is impossible.

The difficulty with this explanation is to account for the fact that north of Cape Parina, although the mountains are just as high as to the south of it, yet rains constantly fall, and the region is remarkably fertile. Moreover, the boundary line between the fertile land and the desert is said to be exceedingly sharp, coinciding in position exactly with the cape. The most apparent fact bearing upon this coincidence is that the Antarctic current, which has closely followed the coast as far as the cape, at this point sweeps out into the Pacific, and turns westerly towards northern Australia. In this same latitude, the eastern coast of South America turns sharply to the northwest, bringing the Atlantic much nearer to the west coast than it was further south. These two facts, however, do not seem sufficient of themselves to explain the sudden change in fertility at this point.*

The climate of southern Peru, where our meteorological stations are located, is extremely uniform. At the observatory station near Arequipa, the temperature seldom falls below 40°

* At the close of the paper, Mr. Clayton suggested that the thermal equator was somewhat to the north of Cape Parina, and that upward air currents would occur in its vicinity, which would tend to cause precipitation, while further south in the vicinity of the tropic, downward cold air currents would tend to dissipate any cloud formations that had already arisen.

Following out this suggestion we may remark that the warm water found just north of the cape would undoubtedly aid in the production of such vertical aerial currents, and we thus have an explanation of the sudden change of fertility above mentioned. I may in this connection refer to the statement of a gentleman who was located for some time in the immediate vicinity of Cape Parina, to the effect that just south of that point was a very small area which was nearly always cloudless. Being situated in the desert, no rain clouds ever passed over it, and being so near the warm fertile region, the fog banks never reached it. The result was a cloudless climate.

F., and seldom rises above 75°. Excepting during the rainy season, the wind blows with great regularity. A sea-breeze from the southwest arises at about ten o'clock in the morning and blows till towards sunset. A land breeze from the northeast arises about midnight, and blows till just after sunrise. The early mornings and the evenings are calm. As we approach the sea and reach the La Joya Desert, the sea-breeze increases in intensity, and comes more nearly from the south, while the land-breeze becomes more feeble.

A curious result of this action is the formation of the so-called *medanos* or sand crescents. These are huge sand heaps of fifteen to twenty feet in height and two hundred or more feet in length, composed of a light colored sand, quite unlike that forming the desert itself, which is reddish brown in color. These crescents, which are very numerous, all face the same way, and all slowly travel together across the desert from south to north. They are composed apparently of sea sand, and take their origin behind any projecting mass, such as a large rock, or pile of railway sleepers. The two ends of the sand heap which collects have less mass in proportion to their surface than the middle, and, therefore, travel faster, giving the heap the crescent form.

The rain storms which reach us in Arequipa come across the continent from the Atlantic. It never rains very much, the mean annual rainfall being probably less than four inches. The rains do not get very far beyond us, and cease entirely before reaching La Joya, which is practically rainless. On the seacoast rain occurs as a great rarity, and these storms probably take their origin in the Pacific.

Our rainy season begins early in January and lasts till the end of March, with some slight variations. It is then practically cloudless, with the exception of occasional thin veils of cirrus, until the first of November. A cloudy season then sets in, lasting through the month, after which it is clear till the beginning of January. The explanation of these phenomena seems to be that the sky is clear while the sun is to the north of us, but that a cloudy zone follows the sun, the front edge reaching us when the sun crosses our zenith early in November. As the sun travels southward, this zone of clouds follows it, the northern edge transiting our latitude the last of November. A short

clear season then intervenes till the sun again turns northward. But now the cloud belt, which has greatly increased in breadth and density, owing to the stationary declination of the sun at the solstice, precedes as well as follows the sun. The sun transits our zenith again early in February, but the southern edge of the cloud belt does not reach us in its northward journey until the sun has passed north of the equator.

An interesting feature of our rain storms is their daily regularity. The rain usually begins at two o'clock in the afternoon, and may sometimes last all night, but the mornings are almost invariably bright and sunny. Rain in the morning is practically unknown, and the time of beginning is very regular. The southeastern part of the valley, ten miles distant from the observatory, receives much more rain than we do, and showers begin much earlier in the day. At the observatory there is scarcely a day in the year upon which the sun does not shine. During the rainy season it rains on the average about every other day, but the rain usually comes every afternoon for a week or a fortnight at a time, the intervening week or fortnight being cloudy in the afternoons.

The rain gauge employed in our observations was of the ordinary form in use by the New England Meteorological Society. It was exposed in a grassy field at a sufficient distance from surrounding buildings, so that it was entirely unprotected by them. Before our regular observations began, a similar rain gauge had been exposed on the top of a flat-roofed house in the city proper. No fault was to be found with either location, but the singular feature was that neither rain gauge would at all adequately record the rain that fell, as far as could be judged by one's personal impressions. Thus, after a moderately heavy rain, lasting one or two hours, in which large drops fell, and which would completely wet one through if he were exposed to it, the rain gauge would only record two or three hundredths of an inch, while the observer, judging from his experience in the temperate zone, would expect that at least as many tenths had fallen.*

* This statement was confirmed by Mr. A. L. Rotch, who had passed several weeks at the observatory. He also mentioned that the wind, especially in the early morning, seemed frequently very boisterous, yet it was most unusual for the anemometer to record more than twenty miles an hour.

The observatory now has four meteorological stations in this region,* all within one hundred miles of one another. The first is at Mollendo on the sea coast, — altitude 100 feet. The second is at La Joya, in the desert, altitude 4,140 feet. The third is at the observatory in the Arequipa oasis,—altitude 8,060 feet. The fourth is at the Ravine Camp upon Mt. Chachani, — altitude 16,600 feet. Observations have now been continued at all of these stations for over a year, and at the observatory for more than two years, and it is hoped that a future discussion of them will lead to a much more accurate knowledge of the meteorology of this portion of the world than we at present possess.

HARVARD COLLEGE OBSERVATORY, Nov. 3, 1893.

A SOUTH AMERICAN TORNADO.

W. G. DAVIS, DIRECTOR OF THE ARGENTINE METEOROLOGICAL OFFICE.

[Authentic accounts of tornadoes in the Southern Hemisphere are so rare that the following description of one in the Argentine Republic, by Mr. W. G. Davis, Director of the Argentine Meteorological Office, is of special interest. It is translated, with his permission, from his report to the Government, for the year 1891–92. The illustrations do not there appear. — A. L. R.]

THE most remarkable phenomenon of the year was the tornado which, on the afternoon of the 13th of November, 1891, devastated the village of Arroyo Seco, situated on the railroad from Buenos Ayres to Rosario, and thirty-one kilometers from the latter town. It caused the death of ten persons and wounded more than eighty, and of the fifty or sixty houses of which the village was composed, only five were uninjured, the greater part of the others, constructed of brick, being entirely destroyed.

The atmospheric conditions which gave rise to this disturbance, and caused its motion and destructive force, had a remarkable similarity with those which in the west of the United States are known by the name of *tornadoes* and which are distinguished from cyclones by a less extension (both in length and in a width of some three hundred and fifty meters only, whilst the cyclone may cover hundreds of leagues) and by a much less violence, especially of the wind's vertical component.

*A fifth has recently been established by Prof. S. I. Bailey upon the summit of the Misti, at an altitude of 19,200 feet.

The series of observations for the month of November furnishes the data for a complete investigation of the conditions which gave rise to and developed the disturbance, but this detailed study will be published later and only a brief *résumé* is given here.

TEMPERATURES AND WIND DIRECTIONS.
2 P.M. NOVEMBER 13, 1891.

During the interval from the night of the 12th to the morning of the 14th, a barometric depression traversed the Republic from the west to the east. At 7 A. M. of the 13th, the centre of the depression was in the east of the province of Rioja and in the northwest of the province of Cordoba; at 2 P. M. it had advanced to the central part of Cordoba; at 9 P. M. to the south of Santa Fé, and on the following morning at seven o'clock it had passed to the east of the city of Buenos Ayres, but having its major axis still nearly in a north and south line. The second chart exhibits the movement of the depression from November 12 to 14, the isobar giving the lowest pressure in millimetres.

At Fisherton, forty kilometres northwest of Arroyo Seco, the barograph registered a fall of 7 millimetres in the six hours pre-

ceding the tempest, with sudden fluctuations between 5 and 6 P. M. The isothermal lines for 2 P. M., of the 13th, showed great differences of temperature, and a comparatively limited area. The temperatures are plotted in centigrade degrees on the first chart and the wind directions are indicated by arrows. On

MOVEMENT OF BAROMETRIC DEPRESSIONS.

the boundary to the north of Santa Fé, the observations gave temperatures above 35° C., with a northerly wind ; at Fisherton, 28° with a southwest wind ; at Capilla del Señor, only 18° with a southerly wind ; and in Buenos Ayres, 21° with the wind southwest. It is precisely from these violent contrasts of temperature, with the corresponding differences in the humidity of the air, that arose the initial conditions producing the tornado.

From the testimony of numerous residents of Arroyo Seco, and from an inspection of the ruins, the following facts relating to the disaster have been obtained : The day had been warm, with a violent wind from the north and north-northwest, during the afternoon, until a quarter of an hour preceding the tempest ; then followed a complete calm, with the atmosphere described as suffocating. At 5 P. M., or a little earlier, there was formed in the south and southwest a dense cloud of a blue-black color,

which rose slowly to an altitude of 20° or 30°; at the same time there appeared in the north great cumulus clouds, white as snow, with their summits reaching nearly to the zenith. Some five or ten minutes before the arrival of the tempest, a twisting and boiling column was seen to detach itself from the cloud mass in the south, which, with a gyrating motion and a dull noise, broke over the town in all its fury at 5.53, and after four or five minutes of complete darkness, left it in ruins. From an inspection of the débris a few days afterwards, it was easy to obtain abundant evidence of the gyratory motion of the storm, and to recognize that it was a veritable tornado of the sort which are so destructive in the west of the United States.

The general direction of its path was from southwest to northeast with a rotary motion of the wind from *right to left.* The width of its path of maximum violence did not exceed five hundred meters, the railroad station being in the middle of it; at a distance of not more than eight kilometers to the southwest of the village the first traces of damage were found, and up to what point its original violence lasted it was impossible to determine, but it was proved that soon after crossing the river and entering the province of Entre Rios, its force was gradually dissipated. In regard to the pressure and velocity of the wind, an approximate idea may be formed by the force required to throw down buildings and to raise and carry away railroad cars. Of the twenty-one box and flat cars standing upon the line and sidings, seventeen were upset, some with their wheels in the air, others broken in pieces, and one loaded car, having a total weight of fourteen thousand kilograms, was thrown thirty meters to the west of the road. The freight shed, measuring twenty-six by ten meters, constructed of galvanized iron, was raised from its foundation, and turning over in the air was thrown against the station. (The accompanying illustration is made from a photograph.) Some of the plates of this building were found at Isla del Rio, a distance of over two miles. A most extraordinary feature was that the front wall of the station which received the blow of the shed suffered little damage, whilst the opposite wall, fifty centimeters thick, was so bent that it had to be rebuilt and the interior partitions, twenty centimeters thick, were for the most part entirely thrown down; this phenomenon can only be explained by the difference in

EFFECT OF THE TORNADO AT ARROYO SECO.

atmospheric pressure between the inside and outside of the building, due to its sudden diminution outside at the first gust of wind, so that the air confined inside acquired for the moment an explosive force. Employing all available data it results that the force of the two wind components (vertical and horizontal) exerted a pressure of one hundred and twenty-five pounds per square foot, but probably for a few seconds only.

An investigation of the causes which produced the tornado, shows them to be the differences of temperature and humidity in adjacent strata of the atmosphere, there being below hot and dry air which was consequently lighter, whilst above it was cold and saturated with moisture. By the weight of the upper stratum an ascending current was induced — in the same manner as the vapor from boiling water (which is formed chiefly at the bottom of the vessel containing the liquid) rises to the surface — and, an opening into the upper stratum once effected, there was formed a vortex giving rise to a rotary motion by the interchange of the two airs of different density, and these forces being put in action the development of the tempest was the work of a few minutes.

At nine o'clock of the same afternoon, the city of Goya suffered a similar visitation, which was attended with less loss of life and property; this storm had its origin a few leagues south the city, and was of the same character as that at Arroyo Seco.

ERRORS OF THE PSYCHROMETER.

PROF. H. A. HAZEN.

IN the July number of the Quarterly Journal of the Royal Meteorological Society of London there is a decidedly interesting contribution to the literature of the psychrometer in a paper by Mr. W. W. Midgley. In an investigation of moisture conditions in cotton mills, he found that in the mill psychrometer the water cup for the wet bulb was only 2½ inches from the dry bulb, instead of 4 inches as in the standard. In some comparisons between a standard and the "mill," he found the dry bulb of the former 7.3° higher in one case and in the average of 18 observations 4.2° higher. He then moved the cup of the

"mill" 4 inches away and a second series of 17 gave the standard 3.9° higher value than the "mill." He then wiped the dry bulb of the "mill" quite frequently, and in 13 comparisons the standard read 1.2° higher than the "mill." It is difficult to account for the change in the third series unless wiping the thermometer had the effect of raising the temperature and a reading was made before all the extra heat had been radiated. We have just seen that removing the cup to a distance of 4 inches in the second series had no effect upon the reading, so that the water could not have had any influence one way or the other. The wet bulb temperatures were uniform in all three sets and the two read nearly alike.

An interesting discussion followed. Mr. Gaster stated that from observation he was satisfied that the proximity of the water had no material effect on the reading of the dry bulb. Another stated that in one series of readings, when the water cup was only one half inch from the dry bulb, 8.5 per cent of the readings were 1° Fahrenheit *less* than the standard. With the cup 1 inch away the temperature was too low in fine dry weather, but was generally higher in damp weather. Another member thought that the differences found by Mr. Midgley (amounting in one case to 8°) must be due to the condensation of water on the dry bulb from the water cup.

It seems almost incredible that such a study and discussion should arise on this subject after all the investigations which have been made recently. Ten years ago it was recognized universally that the psychrometer was very unreliable. It has been shown, however, that all the difficulty vanishes when a uniform ventilation is adopted. But this is not all. It is extraordinary that anyone should for a moment think that a dry bulb can by any possibility read 8° too low because of the condensation of moisture upon it from a cup 4 inches away. The crudest sort of an experiment would show at once that no effect could arise from such a cause. In these experiments the dew point of the air was from 30° to 40° lower than the dry bulb temperature, hence no moisture whatsoever could condense upon the dry till its temperature had been lowered 30° to 40°.

To test the question of the influence of an open water cup upon the readings of a dry bulb, four thermometers were arranged in a straight line so that the distance between them was 6, 3,

and 5 inches, that is, the distance between the first and fourth was 14 inches. A cup 1½ inches in diameter, full of water, was placed so that the centre of the water surface was directly under the second thermometer and 1 inch below the bulb. The air in the room was perfectly still, thus giving an opportunity for a maximum effect. No difference could be detected after several hours in an air whose relative humidity was 50 per cent. The surface of the water was then raised to within one half inch of the bulb and then a maximum lowering of 0.2° to 0.3° was observed. This lowering may have been due to the fact that the water in the cup was at a lower temperature than the air, or the presence of the cup may have had a slight effect through radiation or reflection, or the air very near the water may have been slightly cooled by the vapor passing off of the water at the temperature of evaporation (about 16° lower than the dry bulb). Whatever be the true explanation, it must be admitted that Mr. Gaster was entirely correct in his statement, and that the temperature of a dry bulb will not be affected by a water cup situated two inches away if both are in free air.

AUG. 21, 1893.

CURRENT NOTES.

NEW ENGLAND METEOROLOGICAL SOCIETY.

THE twenty-eighth regular and tenth annual meeting of the New England Meteorological Society was held at the Massachusetts Institute of Technology, Boston, on Oct. 21, 1893. Sixteen persons were present.

The secretary read the following report: The past year has not been an eventful one to the society. Three regular meetings have been held as usual, that of April being in Cambridge. The membership numbers ninety-one, showing a small decrease from last year, there having been three deaths (Messrs. Horsford, Hodges, and Pike), and four resignations; while one new member has been elected. The report on the investigation of thunder-storms in New England during the summers of 1886 and 1887 has been completed by Mr. Ward, and is now published in full in the Annals of the Harvard College Observatory; copies of the report have been sent to all members during the past summer. In this connection it may be said that the studies carried on under the society in 1885, 1886, and 1887, with those undertaken for the Weather Bureau in 1892 by Mr. Ward, give us a much fuller knowledge of thunderstorms in New England than in any other part of the country. The payment of seventy-five dollars, voted by the Council, was made during the year to the New England Weather Service, and the Bulletin of that Service has been regularly issued and sent to our members in return. A similar payment might be usefully applied to the same purpose for another year. It is suggested that the action of the society for the coming year might be especially directed to the question of meteorology in the schools, where suggestions as to methods of teaching might be of service. The AMERICAN METEOROLOGICAL JOURNAL should also receive such support as the society can give it, as it is the only publication of the kind in this country.

The treasurer reported that the Bache Fund for the study of thunder-storms has now been all expended; that a balance of $30.55 remains on hand from the Elizabeth Thompson Fund for the study of rainfall in cyclonic storms, carried on by Prof. Upton; and that a balance of $40.85 remains from the general fund. The treasurer announced that, assuming the receipts from membership fees to remain practically constant, it would be possible, by means of a special rate of subscription for the AMERICAN METEOROLOGICAL JOURNAL, allowed to the society by the publishers, Messrs. Ginn & Co., of Boston, to give the JOURNAL to all our members for the coming year, and still have funds sufficient for the current expenses of the society. In this way, out-of-town members, who seldom can attend the meetings, and who have heretofore received only reprints from the

JOURNAL, containing the proceedings of the three meetings each year, can receive the JOURNAL for the whole year, in which many other articles than our proceedings will be found.

Prof. Upton advocated the adoption of this arrangement; and Prof. Niles remarked on the means of influencing the method of teaching meteorology in the schools. On motion, it was voted that arrangements be made for the distribution of the AMERICAN METEOROLOGICAL JOURNAL to the members of the society; and that the question of meteorology in the schools be referred to the Council with power to act.

The officers of the past year were re-elected, as follows: President, Prof. W. H. Niles, Massachusetts Institute of Technology; Secretary, Prof. W. M. Davis, Harvard College; Treasurer, Mr. R. DeC. Ward, Harvard College; Councillors, Prof. W. Upton, Ladd Observatory, Brown University; Mr. A. L. Rotch, Blue Hill Observatory; and Mr. C. H. Webster, Nashua, N. H.: Mr. F. B. White, of Cambridge, Mass., was elected to membership.

Scientific communications were made by Prof. W. H. Pickering, on "Meteorological Observations in Peru"; by Mr. H. H. Clayton, on "Six and Seven Day Weather Periodicities"; and by Prof. W. M. Davis, on "Terrestrial and Continental Monsoons." The substance of Mr. Clayton's paper was published in the JOURNAL for November; the other papers appear in this number of the JOURNAL (the latter paper, under the title "The Winds of the Indian Ocean").

On Sunshine. — In the August number of the "Scottish Geographical Magazine," Mr. H. N. Dickson, F. R. S. E., has an article on "Sunshine," in which he mentions some of the difficulties encountered in estimating the duration or intensity of sunshine by measuring its effects. Sunshine recorders give data of duration, and of these recorders photographic recorders give the duration of "actinic sunshine," burning sunshine recorders of direct sun-*heat*, and cloud observations an estimate of direct sun-*light*. Yet in each case there is an arbitrary inferior limit of sensitiveness which is different in every case. The eye, used in cloud observations, does not give continuous records, but when these observations are sufficiently frequent, they show that in general records of direct sun-*light* follow the indications of those of direct sun-*heat*. The burning sunshine recorder is undoubtedly the best, so far as scientific meteorology is concerned. The photographic sunshine recorder is, however, of importance in furnishing data as to light and actinic effects in connection with the needs of plants and animals.

"Bright sunshine" Mr. Dickson defines as meaning "a condition such that rays are transmitted through the atmosphere which are capable of producing heat effects exceeding a certain minimum intensity, a minimum determined by the circumstances of the instrument employed in recording."

The highest percentage of sunshine is found in districts where the annual range of temperature is the least. The variation in the amount of sunshine in different months is evidently due, in great part, to the changes in the

paths of cyclones from month to month. The northwest of Ireland and of Scotland receive very little sunshine in the summer and early autumn, while in the late autumn Ireland generally receives more sunshine than most of England. On an examination of van Bebber's monthly charts of cyclone tracks, it is seen that in September and October the first-mentioned districts are on or very near the main line followed by depressions approaching from the Atlantic, while the southern coast of England is at this time to the left of a track running up the Channel. In November this latter track shifts northward, increasing the cloudiness over England, while the track, which is over Ireland in September and part of October, moves southward into St. George's Channel. The effect of the cyclonic tracks is naturally most marked in the winter, when the cyclones are most frequent. The general form of the sunshine curve is a strong minimum in winter, a steady increase to a maximum in May, a secondary minimum in June and July, and a second maximum in August.

Mr. Dickson's article is illustrated by a map showing the mean annual sunshine of the British Isles, on five and ten year averages. The map is colored in different tints to indicate different amounts of sunshine, and is a striking and useful addition to our fund of material concerning the meteorology of Great Britain.

The Bokhara Typhoon of Oct. 8–12, 1892. — One of the most disastrous typhoons of the year 1892 has been made the subject of an address before the Shanghai Meteorological Society, by Rev. S. Chevalier, S. J., the president of the Society, and director of the Zi-Ka-Wei Observatory. The address has been printed and contains many points of interest. The conditions preceding the formation of this typhoon do not point to the existence of an anticyclonic area preceding or all around the centre of the storm, although such a distribution of pressure has been generally asserted to be one of the accompaniments of a disturbance of this kind. The typhoon in question was first reported at the southeast of Luzon on Oct. 7. It passed nearly centrally over South Cape, Formosa, at 1 P. M., of Oct. 10, and then assumed a northerly and afterwards a northeasterly direction, crossing the island of Formosa during the night, and finally disappearing on the western coast of Japan on Oct. 12. The barometric curve obtained at South Cape is quite symmetrical. After 9 P. M., of Oct. 9, the fall of the barometer increased decidedly. The wind was blowing from northeast or east-northeast, with a force of 9 to 10, until 6 or 8 A. M., on the 10th. At 9 A. M., it increased in violence, veering to east-northeast. At noon it blew with hurricane force from the east, the barometer (not reduced to sea level) marking 28.15 inches at 1 P. M. At 3 P. M., the wind had veered to south, blowing with the same violence, and at 6 P. M. it was southwest, and was abating.

Father Chevalier discusses at some length several points in connection with this typhoon, referring to M. Faye's article in this JOURNAL (Vol. VI.), on the "Theory of Storms, based on Redfield's Law," and to Lieut. Finley's and Prof. Hazen's articles on tornadoes in Vol. VII., of this JOURNAL. His conclusions are as follows: "1. No area of high barometric pressure

can be asserted to exist within 600 to 1000 miles from the centre, either all around it or ahead of it. 2. Save the inner spirals, which appear to be circular or almost so, the whirlwinds have a decided tendency towards the centre of the typhoon. This tendency of the winds towards the centre of the typhoon is well ascertained, not only outside the limits of the typhoon, but within these limits, in the very body of the cyclone. Therefore, an uprush of air must exist, either in the inner or outer spirals. Not to carry this conclusion beyond its logical limits, we have abstained from denying a descending current of air in the inner and circular spirals. 3. Typhoons as well as tornadoes are subject to dipping and rising of their lower part, with the difference, however, that in tornadoes the lower part rises up entirely, while in typhoons only the inner spirals do so, the outer ones continuing to touch the ground."

Artificial Rainmaking in Kansas. — An attempt to produce rain by artificial means was made in Kansas on May 26. A press dispatch from Wichita, of that date, described the event as follows: —

"By preconcerted arrangement between the mayors of the towns of Wellington, Winfield, Arkansas City, South Haven, Caldwell, Hutchinson, and Newton, a simultaneous bombardment of the heavens began at noon yesterday. Cannon and every explosive within reach were brought into requisition, and hundreds of men and boys with guns blasted away at the skies till 2 P. M., when the clouds opened their reservoirs and drenched the earth, the rain continuing four hours. All the country for some miles beyond the radius of these towns was deluged by the heaviest rainfall in eight months. The crop prospects in the eight counties over which the rain fell are wonderfully improved."

The cause of the rain is readily seen on an examination of the weather map for the same morning. An area of low pressure was hanging over the southwestern United States, and the forecast for the day was for "showers." Rain fell, not only in the section where the bombardment was going on, but over all the region roundabout, and to the westward. The whole of Eastern Kansas, and a large part of Nebraska, Missouri, Iowa, and Illinois received abundant rains.

*Second Circular relating to the Hodgkins Fund Prizes of the Smithsonian Institution.** — In answer to inquiries, and in further explanation of statements made in the Hodgkins circular, it may be added that *any* branch of natural science may offer a subject of discussion for the Hodgkins prizes, where this subject is related to the study of the atmosphere in connection with the welfare of man.

Thus, the anthropologist may consider the history of man as affected by climate through the atmosphere; the geologist may study in this special connection the crust of the earth, whose constituents and whose form are largely modified by atmospheric influences; the botanist, the atmospheric relations of the life of the plant; the electrician, atmospheric electricity; the

* See this JOURNAL, Vol. X., page 142.

mathematician and physicist, problems of aerodynamics in their utilitarian application; and so on through the circle of the natural sciences, both biological and physical, of which there is, perhaps, not one which is necessarily excluded.

In illustration of the donor's wishes, which the Institution desires scrupulously to observe, it may be added that Mr. Hodgkins illustrated the catholicity of his plan by citing the work of the late Paul Bert in atmospheric electricity as a subject for research, which, in his own view, might be properly submitted for consideration in this relationship.

While the wide range of subjects, which the founder's purpose makes admissible, cannot be too clearly stated, it is equally important to emphasize the fact that the prizes in the different classes can be awarded only in recognition of distinguished merit.

S. P. LANGLEY, *Secretary.*

WASHINGTON, April 28, 1893.

Temperature and Precipitation in California during the Year 1892. — The "Annual Meteorological Review of the State of California" for the year 1892 has recently been issued by the California State Weather Service. It is a neat octavo pamphlet of forty-six pages, and was compiled by Mr. James A. Barwick, director of the Weather Service and meteorologist to the State Board of Agriculture. From this report we extract the following data: —

Temperature. — Normal for State, 60.1°; average for the year 1892, 58.7°; departure from normal, — 1.4°. Highest annual mean, 72.6° at The Needles, San Bernardino County; lowest annual mean, 49° at Susanville, Lassen County. Highest temperature, 117° at The Needles; lowest temperature, 10° at Susanville.

Precipitation. — Normal for State, 23.41 inches; average for the year 1892, 28.74 inches; departure from normal, +5.33 inches. Greatest annual precipitation, 83.88 inches, at Upper Mattole, Humboldt County; least annual precipitation, 3.07 inches at The Needles, San Bernardino County.

The table showing the number of clear and fair days at the stations in each month and for the year is very interesting. The smallest number of clear and fair days at any station during the year was 221; the largest number was 356, at Sweetwater Dam, in Southern California.

The Diurnal Period of the Barometer on Chachani. — Mr. A. Lawrence Rotch has received the following letter from Dr. Hann, under date Vienna, Oct. 16, with reference to the article on "The Highest Meteorological Station in the World," printed in the October number of this JOURNAL: —

"I have just read with much interest your description of the Chachani Station, and rejoice over the publication of the Arequipa and Chachani observations. The reason that the daily period of the barometer on Chachani does not accord with that on Mont Blanc is not because of the topography, but on account of the latitude. In such low latitudes the double daily oscillation is so large that it does not disappear at 16,000 feet, as it

does in latitude 46°. On the Dodabetta Peak, over 8,000 feet high, there are almost the same oscillations as at Madras, but on the equally high Faulhorn, in Switzerland, there is little more than a single one."

Nebraska Weather Record. — The Nebraska State Weather Service is the latest addition to the line of State Services which issue their monthly bulletins in the form of a publication containing not only the usual data, but also other items of interest to the observers. The first number of this new publication was issued on July 15, and two numbers are at hand. It is an eight page sheet, and is well printed and edited. The editor is Mr. George E. Hunt, Local Forecast Official for Nebraska, and Director of the State Weather Service. The object of the *Nebraska Weather Record and Monthly Crop Review* is to preserve and put in permanent reference form the data collected by the Weather Service of the State. The subscription price is to be twenty-five cents per year, which is certainly low enough to insure the paper a good circulation. As another proof of the growing interest in the study of meteorology in this country, the *Nebraska Weather Record* is a welcome addition to the meteorological publications of the United States.

Lake Storm Bulletin. — The United States Weather Bureau has begun the issue of a series of "Lake Storm Bulletins" in the interests of lake navigation. The Bulletin will be issued hereafter whenever a severe storm passes across the lake region during the season of navigation. Bulletin No. 1 (issued Oct. 7) describes the severe storm of Oct. 4–7, which attained its greatest energy Oct. 6, with a velocity at Chicago of sixty miles per hour. In size the Bulletin is about nineteen inches square, and comprises, in addition to descriptive text, the weather charts of Oct. 5, at 8 P. M., Oct. 6, at 8 A. M. and 8 P. M., each about eight inches square.

Death of Dr. Carl Lang. — We regret to announce to our readers the death, on Sept. 23, 1893, of Dr. Carl Lang, Director of the Royal Bavarian Meteorological Station at Munich, and *Privatdocent* in the Ludwig-Maximilians University and in the Royal Technical High School.

Erratum. — In the line of text under the view of the Chachani Station, published in the October number of this JOURNAL, instead of *north* read *northeast.*

EDITORIAL NOTE.

IT gives us great pleasure to announce to our readers that, at the Annual Meeting of the New England Meteorological Society, held in Boston, Mass., Oct. 21, 1893, it was voted to send a copy of this JOURNAL to each of the members during the coming year. Such an expression of approval on the part of so well known and so active an organization as the New England Meteorological Society is in the highest degree gratifying to the editor. It shows that the JOURNAL is deemed, by the Society, an essential for those who are interested in meteorology, and who wish to keep informed as to the progress of the science.

CORRESPONDENCE.

A DESTRUCTIVE CYCLONE.

Editor of the American Meteorological Journal:

The August *Monthly Review* of the Iowa Weather and Crop Service contains an article under the above caption that is of great interest to Eastern readers. We read: "The cyclone struck the coast of Florida on Aug. 27, raging with terrific force through Eastern Georgia, South Carolina, North Carolina, and Virginia, causing a great loss of life and immense destruction of property in its pathway through those States. The loss of life on the islands and lowlands along the coast was caused mainly by the heavy waves, and the number of victims is computed to be more than one thousand. Thousands of buildings were wrecked, trees were broken or uprooted by the force of the hurricane, and the crops within a belt over a hundred miles were well nigh completely ruined. In the little town of Kernersville, N. C., over one hundred buildings were destroyed. The property loss is estimated at over $10,000,000. . . .

"It was a veritable cyclone, and it should be noted that it differed widely and materially from the Pomeroy-Iowa storm of July 6, which is so frequently miscalled a "cyclone." The Pomeroy tornado was less than two thousand feet wide, its path was about sixty miles long, and the duration of its destructive force was about two hours. The eastern cyclone covered a belt five hundred to one thousand miles wide and three thousand miles long, and it was in active operation four or five days. In Georgia and the Carolinas it raged nearly two full days. . . .

"The people of the east know by experience something of the vast breadth and general destructiveness of a cyclone. And when they read in the western papers and our press despatches that some Iowa, Missouri, or Kansas town or farming section has been struck by a "cyclone" they are impressed with the idea that the western people are most awfully tempest-tossed and greatly to be pitied.

"Our prairies are occasionally ploughed by small-bored tornadoes, but they are mere pin scratches compared with the immense sweep of the cyclones which are born of the heat and moisture of the tropical waters. Tornadoes occur at the east and south as well as in the west, but the Mississippi valley is happily exempt from the cyclones and hurricanes of the West Indies type."

Those readers over whom this storm passed will be a little amused at this attempt to prove that the western tornado cannot be regarded as anything like as severe as storms of this type in the east. In Washington, D. C., there were a few weak trees or branches blown down for two or three hours,

but there was no destruction, and the highest wind was barely 50 miles per hour. Since this storm originated on the ocean, as a natural consequence the winds, meeting with little friction over a water surface, were very high, and caused enormous waves on the immediate coast, and nearly the whole loss was due to these waves rather than to the wind directly. As the storm moved along the land it lost a good deal of energy. So far as now known the only damage in the interior was at Kernersville, N. C., and in this case, unfortunately for the western critic, the destruction was wholly caused by a veritable tornado, like those felt in the west, which occurred in the southeast quadrant of the general storm, just as they do in the west. There is hardly a month in which such a general storm as this is not felt in the west. A good illustration of this is to be found in the storm of Oct. 6 in the lake region, in which the wind reached 60 miles per hour at Chicago. There is no doubt that the tornado evil has been greatly exaggerated in the west, and it is gratifying to learn that people are beginning to understand this. Surely there is no need of exaggerating the general storms of the east in comparison with these tornadoes. The tornado has a narrow sweep, but it takes everything with it; it is an accompaniment of a general storm which often has very high winds, but not destructive. In the east we have only the general storm, and loss of insecure roofs and a few tree branches or weak trees. It is very unfortunate that the term cyclone or hurricane is applied to these storms after they leave the water. I happen to know of scores of people who were much terrified at the reports of a cyclone. These persons had always associated in their minds the tornado of the west in connection with the word cyclone, and very much feared such a visitation. It would be vastly better to discard "cyclone" in all publications, or, at least, until its false import has been removed. The words "wind-rush," or, for the severer storms, "tornado," will answer for the western destructive storm, and the words "Atlantic," "Gulf," or "severe Atlantic," etc., will answer for the general storms of the southern type. This seems all the more necessary since in nearly all scientific publications relating to meteorology a still greater confusion has arisen from the use of the word "cyclone" to represent any storm, no matter how weak, which has winds blowing spirally toward a common centre. The word was first applied to storms taking their origin in the tropics, and if ever used it should be confined to such storms. The term "hurricane" is understood to represent any wind of 90 miles per hour or more. It should not be applied to the general storm.

H. A. Hazen.

Oct. 7, 1893.

CLOUD-BURST IN TENNESSEE, AUG. 3, 1893.

Editor of the American Meteorological Journal:

Although enormous rainfalls of from 10 to 35 inches a day are sometimes reported from foreign countries, they are so rarely reported from stations in the United States, that I think the following description of a cloud-burst, which occurred in Smith County, Tennessee, on Aug. 3, 1893, will be of interest to the readers of the Journal: —

The weather had been very warm and sultry for some three days previous to the storm, gradually getting unbearably warm. Almost a calm prevailed throughout the district on the evening before the storm, and all animal life seemed to almost suffocate from the intense heat. In the morning about 5 A. M., people were suddenly awakened by an enormous downpour of rain, nor did it cease until the water in small brooks had spread over fields and gardens, carrying total destruction as it went. Near larger brooks, fences, parts of houses, barns and farming implements suffered fearfully.

The path of the storm was from N. E. to S. W., which differs very greatly from the average. There being only one voluntary meteorological station near this storm, it was very difficult to obtain data; but the writer rode over the greater portion of the tract with the following results: the destructive path was about twenty-five miles long and sixteen miles wide. The observer at Riddleton, who was only on the edge, recorded 8.31 inches of rain in five hours. At four other places rain was recorded in quite a rude manner, such as with oyster cans, washtubs, etc. One person caught a two-pound oyster can full twice, and had it about half full the third time.

One old lady caught a washtub full in about an hour of the hardest rain. Of course such measurements as these cannot be taken as giving accurate amounts of fall, still, comparing the relative heights of brooks at the centre with those near the gauge, it would seem underestimating to say that three times as much rain fell in the centre as did at the gauge, making it probable that twenty-four inches fell near the centre. The northern portion was not accompanied with hail as was the southern, but so severe was the hail in the southern portion that almost all vegetation suffered more or less, corn blades were split in threads, and from 10 to 40 per cent was blown and washed down. Apples, peaches, and pears were greatly damaged, the fruit being blown off and the branches badly broken.

So high were the neighboring brooks that when several came together in a creek or small river, the force of the water was sufficient to uproot large trees and move stones that weighed several tons, and where each of these creeks emptied into the Cumberland River, a dam composed of trees, gravel, and large stones was formed across the river on the down stream side, completely filling up the channel of the river until the water (which was very low) was forced to flow through numerous small breaks in the dam.

Another unusual fact was that the storm was divided into two distinct areas. The general path of the storm was about N. E. to S. W., while the Cumberland River runs nearly E. and W. In nearing the river, the severity of the storm seemed to diminish gradually until within about 300 yards of the river the only perceptible trace was the enormous overflow of the streams; it again increased when about the same distance across the river. The general wash was greater on the north side of the river than it was on the south, while the destruction by hail was equal to that of the wash.

The electrical display was not very marked, and in asking for the general wind direction, people would say from every direction, and the direction of the path was taken from the beginnings and endings of the several places visited along the tract.

Total duration from first beginning to last ending, 3.50 A. M. to 12 M. Mean duration at any one place 4 hours and 30 minutes.

W. H. FERGUSSON.

BLUE HILL OBSERVATORY, September, 1893.

THE BIRTH OF A TORNADO ON A MOUNTAIN TOP.

Editor of the American Meteorological Journal:

On Sept. 11, 1893, a tornado was observed in the interesting stages of formation, growth, and progressive motion, at Highlands, N. C. The village is situated on a plateau just over the crest of the Blue Ridge, on the northerly side, at an altitude of 3,817 feet.

For three days previous a cyclone of little energy had been hanging over the Gulf States and Tennessee, and had caused almost continuous rains in the mountains of southwest North Carolina, though the precipitation was very light in the low country. At Highlands the rainfall was 10.33 inches, between 8 P. M. Sept. 7, and 8 P. M. Sept. 11, and there was no sunshine during this time. The wind had been easterly and then southerly, of moderate force all the time, ranging from 0 to about 8 miles an hour, and much of the time it was hardly noticeable.

At 5 o'clock P. M., local mean time, during a short interval when no rain was falling, smoke from a chimney was seen to be moving slowly to the southward, indicating a sudden shift of wind from south to north. Further observation showed that this current was local, the wind elsewhere being southerly and very moderate, less than four miles an hour. Low lying detached clouds and fog patches plainly showed the air currents. Soon the velocity of the current from the north increased, and between it and the observer, who was looking toward the west, was seen a current of equal velocity moving in the opposite direction; viz., from south to north, both currents *apparently* being rectilinear, with parallel, horizontal courses. The amplitude of these movements was estimated to be from a mile to a mile and a half. The velocity of the opposite currents continued to increase rapidly, and overhead a black nimbus was noticed with a ragged under surface, about 500 feet from the ground. Numerous slender vortices of vapor then appeared reaching up to the storm-cloud with a wavy motion, looking somewhat like streams of smoke from chimneys on a still morning. Soon the movement of the winds became plainly rotatory (*contra clockwise*), increasing in force with a diminishing radius of gyration. The cloud overhead appeared to contract, the ragged projections underneath to unite in a single pendant mass, the ascending vapor vortices disappeared; and the whole system then moved off toward the north, at the estimated rate of fifteen to eighteen miles per hour, with a diameter judged to be a quarter of a mile, and disappeared, rapidly rotating, behind the end of a mountain. The time covered by the observations was from ten to fifteen minutes.

This seems to be a case where one may reasonably look to the latent heat given out by condensation, as the chief source of the buoyancy necessary to start the whirl; and it is likely that the young tornado soon ran out of the conditions necessary to its sustenance and growth.

FRANK W. PROCTOR.

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THUNDERSTORMS IN NEW ENGLAND DURING THE YEARS 1886 AND 1887.

ROBERT DEC. WARD. *Thunderstorms in New England during the Years 1886 and 1887.* Annals of the Astronomical Observatory of Harvard College, Vol. xxxi., Part II., 1893.

Mr. Ward has so thoroughly studied the thunderstorms of New England, and has so carefully read up the literature of the subject that he may well be called an expert on this subject; and it is fortunate that he has given meteorologists so full a paper on the thunderstorms of New England. In this paper he gives in the first place a detailed account of the individual thunderstorms, and in the second place a brief discussion of the storms for each year. His method is to give the general weather conditions prevailing over and in the vicinity of New England on the dates of each storm; then to give the places and times of thunder and rain; and finally to give the special notes about the storms, such as the appearance of the clouds, the changes in the winds, temperature, etc. The changes occurring during the thunderstorm of Aug. 12, 1886, are illustrated by reproducing the records made by the self-recording instruments at Blue Hill, showing the pressure temperature, humidity, and rainfall. The charts were selected as giving a typical illustration of the changes which take place during thunderstorms. These are a sudden temporary increase in pressure and humidity, and a sudden temporary decrease in temperature; all of which only last during the continuance of the thunderstorm, although the pressure and humidity rarely fall so low, and the temperature rarely rises so high as they were before this thunderstorm. The fall of rain during the thunderstorm was very rapid, and mest of it fell within a few minutes.

In the two summaries Mr. Ward gives the number of thunderstorms observed during each month of the year. These show a decided maximum of thunderstorms in July, and a decided minimum, amounting to an almost entire absence, during December and January. The hours of greatest frequency of thunderstorms were found to be between 5 and 7 P. M. in 1886, and between 3.30 and 5.30 P. M. in 1887. All these results are a confirmation of the usual opinion that thunderstorms are the accompaniments of high temperature, as they occur most frequently at the warmest time of the year, at the warmest time of day, and on the warmest days. But apparently in contradiction to this is the statement in the report that, "The thunderstorms of the winter months occurred mostly in the evening or during the night, and on the sea coast." But this contradiction may be only apparent, for, as Prof. Davis points out, the air in winter is warmer on the sea coast

than inland; and on cloudy nights the radiation is very intense from the upper surfaces of the clouds, while the air near the earth's surface is protected from radiation, so that it is relatively much warmer than the air around and above it. Hence, the conditions are favorable for thunderstorm production.

The velocity of progressive movement of thunderstorms was found to be about thirty-five miles an hour in 1886, and between thirty and thirty-five miles an hour in 1887. It would have been interesting if the author had given the average velocity for the different months; for, if the storms move with the upper currents they would have a minimum velocity in midsummer. The average direction of motion is not given, but the individual results show that most of the storms moved from west and northwest, which agrees with the prevailing direction of upper currents over New England in summer.

The present writer took the direction of the thunderstorms as given by Mr. Ward and obtained the average direction of thunderstorm movement in each five-degree square of latitude and longitude around the cyclone centre, in the same way that he did for the clouds at Blue Hill; and he found that the thunderstorms had almost exactly the same mean directions in different parts of the cyclone as did the middle level of clouds (15,000 to 20,000) at Blue Hill. That is, in front of the cyclone centre they were mostly from southwest and west; south of the cyclone centre, from west; and west and southwest of the cyclone centre, from northwest.

Mr. Ward found the majority of the storms in 1886 in the southern or southwestern quadrant of cyclones, while in 1887 the majority occurred in the southeastern quadrant. Taking the two years together, the present writer finds the majority of storms about two hundred miles south-southwest of the centre.

It would have been interesting had Mr. Ward investigated the questions as to how far thunder is heard at a distance from the storm, and how far the clouds can be seen. In one or two cases thunderclouds in New Hampshire were seen from Blue Hill, a distance of from sixty to one hundred miles.

It would also have increased the value of the report had Mr. Ward given the number and distribution of the stations reporting thunderstorms.

H. H. C.

BRITISH RAINFALL FOR 1892.

G. J. SYMONS, F. R. S., AND H. SOWERBY WALLIS, F. R. MET. SOC. *British Rainfall*, 1892. *On the Distribution of Rain over the British Isles during the Year* 1892, *as observed at nearly* 3000 *Stations in Great Britain and Ireland, with Articles upon Various Branches of Rainfall Work.* 8vo, London, 1893. Edward Stanford, 40, 223, pages, 10*s*.

Mr. Symons's yearly volume on British Rainfall for 1892 is at hand. From the beginning of the work in 1861, when 168 rainfall reports were sent in, to the past year, when nearly 3000 observers co-operated, the data used

in this investigation have become more and more complete. The present volume contains tables of the total annual rainfall at all the stations, the monthly rainfall at several hundred stations, and data as to heavy rains in short periods, heavy falls in twenty-four hours, relation of the rainfall of 1892 to the average, etc. Among the heavy rainfalls we may note a fall of 3.75 in. in two hours at Tyntesfield, Flax Bourton, Somerset, on July 16. The greatest rainfall of the year was at The Stye, Cumberland, where 172.20 in. were registered, and the least was at Tewkesbury, Gloucester, where 16.25 in. fell.

We cannot but admire Mr. Symons's untiring energy in gathering these data during so many years. Meteorology would be fortunate if it had many more such workers.

RECENT PUBLICATIONS OF THE MARYLAND STATE WEATHER SERVICE.

There is no more encouraging sign of the growing interest in meteorology in the United States than the rapid increase, during the past year or two, of State Weather Services. These Services are now established in every part of the United States, except Alaska, and with their network of observers are collecting valuable data for future study. As is generally known, these Services issue monthly, and, during the growing season, weekly bulletins, which vary in style from single typewritten sheets to well-printed octavo publications of several pages. It is our intention soon to prepare an account of the various State Weather Services, and of their publications; and the purpose of the present notice is simply to call attention to some valuable articles which have recently been published in the "Monthly Bulletin" of the Maryland State Weather Service. The Maryland Service, although established as recently as 1892, has already published a series of articles which have placed its Monthly Bulletin in the front rank of all the publications of its kind in the United States. The papers referred to are valuable as having been written by experts who are thoroughly acquainted with the subjects, and as contributing directly to a better knowledge of the climatic and surface features of the State.

Prof. Milton Whitney, of the Maryland Agricultural College, whose studies in connection with soils are well known, has an article in the Bulletin for January, 1892, entitled, "Relation of Soils to Meteorological Conditions and to Crop Production," in which the general questions of the effect of varying seasons and of different kinds of soils on different crops are discussed from a local point of view, so that the article has a direct interest for the farmers of the State. To the June number Prof. Whitney contributes a paper in the same line, on "The Soils of Maryland," which is illustrated by a map showing the area and distribution of the principal soil formations. Dr. William B. Clark, of Johns Hopkins University, the Director of the Service, who, though primarily a geologist, has given much attention to physical geography and meteorology, takes up the important relation between the climate and topography of his State in a valuable paper

in the March Bulletin, entitled, "The Surface Configuration of Maryland." In this the chief topographic features of the State are clearly brought out, so that anyone may gain a comprehensive view of its surface configuration, a knowledge of which is necessary to the intelligent consideration of the climate of the State. Following naturally after this paper, Dr. Clark has, in the May Bulletin, a carefully prepared article on "The Leading Features of Maryland Climate." This is of special value to the inhabitants of that State, but is also of considerable interest from a general point of view, the climate of Maryland, in the eastern portion of the State, being greatly modified by the ocean and Chesapeake Bay, so that it becomes almost an oceanic or insular climate, while in the other portions it is continental. The peculiar configuration of Maryland, which is the cause of this variety in climate, makes the meteorology of that State particularly interesting to outsiders. "The Medical Climatology of Maryland" is the title of an article in the July Bulletin, by C. W. Chancellor, M. D., late Secretary of the Maryland State Board of Health. This is a general statement of the climatological peculiarities of the State, which supplements the preceding papers. Other articles which deserve mention in this notice are, "The Available Water-Power of Maryland," and "The Public Water-Supply of Maryland," by Dr. Clark, in the May and July Bulletins, and "The Grasses of Maryland," by Basil Sollers, in the August issue.

From this very brief review it will be seen how much the Maryland State Weather Service has done in a short time towards publishing valuable information as to the climate and surface features of the State. The record made by this one Service should inspire the other Services to do similar work, so that instead of the mass of data now lying idle in many of the central stations of the different States, we may soon have numerous publications, based on these data, which shall add to our knowledge of the climates of the several States, and so to the general progress of meteorology in this country.

POPULAR ASTRONOMY.

THE first number of a new magazine entitled "Popular Astronomy" was issued on Sept. 1. Its editors are Wm. W. Payne and C. R. Willard of the Goodsell Observatory of Carleton College, Northfield, Minn. The aim of the editors is to prepare a magazine expressly for teachers and students of astronomy and for amateurs. It is proposed to treat all important astronomical topics in a popular way, without using technical language. The first number is an attractive one, and should secure many friends for the magazine at once. It includes articles by Prof. Winslow Upton, of Ladd Observatory, Providence, R. I., on "Constellation Study"; Prof. James E. Keeler, of Allegheny Observatory, on the "Spectroscope and some of its Applications"; Prof. W. W. Payne, on the "Moon" and on "Jupiters' Comet Family"; H. C. Wilson, on "Astronomy with the small Camera," and other papers of interest. The general articles in the first number are largely introductory, but they give promise of future papers of great interest. The

list of writers who will contribute to "Popular Astronomy" includes, besides those who have written for the first number, the names of E. E. Barnard, of Lick Observatory, S. W. Burnham, late of Lick Observatory, and Geo. E. Hale, of Chicago.

"Popular Astronomy" starts out with an object which should commend t to all who are interested in the growth of astronomical knowledge. We feel sure that there is a field for such a magazine, and that this one will occupy that field well. The price is $2.50 a year.

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(An Asterisk [*] indicates that the publication thus designated has been received by the editor of this JOURNAL.)

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